

Accessibility analysis as an urban planning tool: Gas station location

Citation for published version (APA):

Escobar, D., Cadena-Gaitán, C., & Garcia, F. (2014). *Accessibility analysis as an urban planning tool: Gas station location*. UNU-MERIT. UNU-MERIT Working Papers No. 048
<http://www.merit.unu.edu/publications/wppdf/2014/wp2014-048.pdf>

Document status and date:

Published: 01/01/2014

Document Version:

Publisher's PDF, also known as Version of record

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.umlib.nl/taverne-license

Take down policy

If you believe that this document breaches copyright please contact us at:

repository@maastrichtuniversity.nl

providing details and we will investigate your claim.



UNITED NATIONS
UNIVERSITY

UNU-MERIT

UNU-MERIT Working Paper Series

#2014-048

Accessibility analysis as an urban planning tool: Gas station location

D.A. Escobar , C. Cadena-Gaitán, F.J. Garcia

Maastricht Economic and social Research institute on Innovation and Technology (UNU-MERIT)

email: info@merit.unu.edu | website: <http://www.merit.unu.edu>

Maastricht Graduate School of Governance (MGSoG)

email: info-governance@maastrichtuniversity.nl | website: <http://mgsog.merit.unu.edu>

Keizer Karelplein 19, 6211 TC Maastricht, The Netherlands

Tel: (31) (43) 388 4400, Fax: (31) (43) 388 4499

UNU-MERIT Working Papers

ISSN 1871-9872

**Maastricht Economic and social Research Institute on Innovation and Technology,
UNU-MERIT**

**Maastricht Graduate School of Governance
MGSoG**

*UNU-MERIT Working Papers intend to disseminate preliminary results of research
carried out at UNU-MERIT and MGSoG to stimulate discussion on the issues raised.*

Accessibility analysis as an urban planning tool: Gas station location.

D.A. Escobar^{a*}, C. Cadena-Gaitán^b, F.J. Garcia^a

^aDepartment of Civil Engineering, National University of Colombia, Cra 27 N°64-60, Manizales 17001000, Colombia

^bPhD Research Fellow at United Nations University – UNUMERIT/School of Governance

Abstract

We apply geo-statistical techniques to find relationships between the geographic location of urban "Gas Stations" (GS) and operational features offered by the transport network in Manizales (Colombia). This research is built upon primary information collected during a period longer than one year using GPS (more than 18 million data points). The methodology consists of i) The set-up of the entire urban transport infrastructure network, ii) The calculation of the average operating speeds in the links, iii) The calculation of the global average accessibility offered by the infrastructure network in different transport modes, iv) The calculation of the Spatial Coverage Index, area, population and number of houses covered by the curves of travel time. Graphical results explain the average times invested in reaching a particular GS, and quantitative comparisons between different types of stations are studied. Thus, we establish which sectors of the city are deficient in coverage of this type of activity. The overall results reveal the possibility of reaching a GS in Manizales in an average travel time between 4 and 22 min.

JEL Classification: R32, R41

Keywords: Gas Stations, Accessibility, GPS, coverage, urban mobility, operating speeds, Geostatistics.

Résumé

Nous appliquons des techniques de géostatistique pour trouver des relations entre la localisation géographique des "Stations-service" urbaines et des caractéristiques opérationnelles offertes par le réseau de transports à Manizales (Colombie). Cette recherche est fondée sur des informations originales recueillies pendant une période supérieure à un an, en utilisant le GPS (plus de 18 millions de points de données). La méthodologie consiste en: i) La mise en place de l'ensemble du réseau d'infrastructures de transport urbain, ii) Le calcul des vitesses moyennes dans les liens, iii) Le calcul de l'accessibilité moyenne totale, offerte par le réseau d'infrastructures dans les différents modes de transport, iv) Le calcul de l'Index de Couverture Spatiale, de l'aire totale, de la population, et du nombre de maisons couvertes par les courbes de temps de déplacement. Les résultats graphiques expliquent les délais moyens pour arriver à une station-service particulière, et des comparaisons quantitatives entre les différents types de stations sont étudiées. Ainsi, en établissant quels secteurs de la ville sont déficients en couverture de ce type d'activité. Les résultats complets montrent la possibilité de parvenir à une station service à Manizales, dans un temps de trajet moyen entre 4 et 22 min.

Mots-clé: Stations-service, accessibilité, GPS, couverture, mobilité urbaine, géostatistique.

* Corresponding author information: prof. Diego Escobar. Tel.: +5768879300 ext 50312; fax: +5768879300 ext 50320.
E-mail address: daescobarga@unal.edu.co



1. Introduction

The city of Manizales is located in the centre-west region of Colombia, at 5.4° latitude north and 75.3° longitude west), along the prolongation of the Andean Mountain Range, at 2150 metres above sea level. This research provides an accessibility analysis relating geo-spatial locations for Gas Stations (GS) and the operative characteristics of the road network, with a view to calculating the geo-spatial coverage index of each activity node. To process the data, we used TransCAD® and Surfer® software. Accessibility as a tool has been used infrequently in Colombia, yet its importance is such that it must be understood as an unperceived secondary necessity (Halden, 2011); not an end in itself but rather a medium to achieve essential civic aspects (health services, education, the job market, etc.). In general, accessibility can be considered a crucial competitiveness factor for different regions (Biehl, 1991), thus, those populations that exhibit higher levels of accessibility should over time have accounted for a greater economic success. This close relationship between accessibility and competitiveness means that the improvement of transport infrastructure becomes an essential component of economic development (Holl, 2007). Nowadays, gas can be considered a primary necessity for many people and so must be guaranteed as accessible and attainable. Crucial transport policies in a variety of countries aim at reducing inequality by – among others – guaranteeing greater access to primary necessity goods and services (Jones, 2011). Moreover, we are aware of the fact that ordinary tools for evaluating transport projects often do not reliably measure their contribution to the accessibility levels (to services and opportunities), and in turn to the social implications of this (Bocarejo and Oviedo, 2012). As such, we intend to contribute with evidence on using accessibility analysis as an urban planning tool. The structure of this paper is as follows: section 2 presents a brief literature review; section 3 explains the methods used for calculating the geospatial coverage indices, and overall accessibility. In this section we also describe the construction of the database used; in section 4 we explain the results in detail; followed by the main conclusions in section 5.

2. Literature Review

Accessibility has increasingly become a focus point in territorial planning studies, for both urban and regional transport, during the last 50 years. This approach was initially introduced in the 1920s, in the context of regional economic planning and area location theories (Batty, 2009). Accessibility has been often defined in different ways, and for different academic purposes. For instance, in the transport field, as a measure of the ease in connecting human settlements and activities using a certain mode of transport (Morris et al., 1978), (Zhu and Liu, 2004); however, we are aware of several other accepted definitions for this concept (Pirie, 1979; Jones, 1981; Martellano et al., 1995), with Hansen's (1959, 73) definition being the classic one: "... *the potential of opportunities for interaction*". Accessibility analysis for a territory can be advanced using graph theory (Petrus and Segui, 1991). This implies the application of a morphometric analysis of networks (explanatory assessment) to understand, via partial databases, which is the aspect of the complete network structure; we can thus identify those zones that are characterized by minor accessibility possibilities in relation to the location of one or many particular activity nodes. These types of accessibility analyses are increasingly becoming more important in the evaluation of infrastructure plans and projects (Gutierrez et al., 2010), often implying that the improvement in accessibility levels, is one of the key criteria frequently used in these evaluations. There are various approaches to use accessibility analyses as evaluation tools. Often born out of the conceptual frameworks of urban and regional planning, these approaches aim at a variety of criteria, related with spatial distribution of economic activities (Krugman, 1991; Fujita et al., 1999), economic development (Rietveld and Nijkamp, 1993; Vickerman et al., 1999; MacKinnon et al., 2008), land appreciation and urban density (Alonso, 1964; Kotavaara et al., 2011), sustainability (Cheng et al., 2007; Vega, 2011; Escobar et al., 2013), operativity in modes of transport (Geurs K. & Van Wee B., 2004), social cohesion (Schürman et al., 1999; López et al., 2008), marketing (Geurs K. & Ritsema Van Eck, 2001), tourism (Kastenholz et al., 2012), social networks (Sailer et al., 2012), etc.

Powerful informatics tools have been developed during the last decades to generate spatial analyses, by studying the relationship between geographical databases (Zhu X. & Liu S., 2004). These tools have positively impacted the analytical capabilities of researchers, allowing for the integration of activity node geographical data with other data regarding transport infrastructure, demographics, socioeconomic and geospatial characteristics, etc. In this research we used Geographic Information Systems (GIS) to collect data from various activity nodes identified as gas stations throughout the urban areas of the city of Manizales. When linking these to specific



operational characteristics of the transport infrastructure network, and additional socio-demographic data, we were able to integrally analyse the spatial coverage indices, and thus, generate more accurate values in relation to the actual coverage that the transport infrastructure offers to the local community, in terms of the geographical location of gas stations, and specific structural variables such as area, population and housing units. Using the geospatial visualization capabilities of the GIS, we produced geographical distribution maps of gas stations. These maps allowed us to perform the geospatial coverage index analyses, as proposed by the current literature. Some examples of geospatial coverage analyses, also performed using various informatics developments include the areas of: location and service provision studies (Calcuttawala, 2006; Higgs et al., 2012; Park, 2012), natural resources and agriculture (Gellrich, M. & Zimmermann N., 2007; Tassinari et al., 2008; Arcidiacono, 2010); urban and demographic growth (Huiping, L. & Qiming, Z., 2010); regional studies (Straatemeier, 2008); health (Hernández et al., 2002); amongst others. We have developed a number of interrelated stages in this research. First, we optimized the data pertaining to the full transport infrastructure network, hence going through data collection phases, and an update of the georeferenced network. Secondly, we relate the calculations for the average arc operational speeds. Thirdly, we calculate the Average Overall Accessibility offered by the infrastructure network in the various transport modes analysed; and finally, we calculate percentages for area, population, and housing units which are covered by the average travel time curves obtained through the accessibility analysis, and their relationship with the geospatial location of the gas stations.

3. Methodology

Our methodological approach is composed by five key steps.

3.1. Data collection

A detailed fieldwork was advanced to identify all gas stations located within the urban areas of the city of Manizales, dividing them according to the gas type these distribute, and verifying the correctness of their geospatial location using GPS tracking devices. The data collection took place during a twelve-month period between 2010 and 2011. The GPS tracking devices were activated during normal business hours.

3.2. Update of the georeferenced network

We analysed the current road network, as provided by the municipal administration, and complemented the supplied data with the fieldwork done using the GPS devices. This allowed us to correct and validate the geographical information supplied. The city of Manizales exhibits a network composed by more than 12000 arcs and approximately 9000 nodes.

3.3. Calculating operational speeds and instantaneous speed

GPS tracking devices were installed in different vehicle types (private car, motorcycle, taxi, truck, and public transport buses). We were thus able to record satellite positioning data along a predetermined time interval (every one second). Using this approach, we are able to calculate the average operation speed for each of the arcs that compose the system. Operational speeds were calculated based on the actual direct monitoring data, and reflect the true operational characteristics (including slopes, jam, etc.) of the arcs that compose the network. This is an extraordinary contribution, as accessibility analyses are often performed using assumed operational speeds, depending on the road category (Burns & Inglis, 2007); Nonetheless, other recent accessibility studies also use real vehicle speeds (Li et al., 2011). In order to process the collected data we applied a variety of algorithms. First, to calculate the operational speed for each time interval between two points, we used Equation (1). This parameter is useful when establishing speed variations in a particular arc, and to determine the number of stops.

$$v_i = \frac{3.6}{t} \sqrt{(y_2 - y_1)^2 + (x_2 - x_1)^2} \quad (1)$$

Where: v_i = Speed in km/h; x_1, y_1 = Coordinates for point 1 in metres; x_2, y_2 = Coordinates for point 2 in metres; t = Time interval in seconds between data points.



Secondly, to calculate the average operational speed of a trip for a given n th arc, we used Equation (2). This speed was obtained by examining the relation between arc length and the difference in passing times for the starting and ending node.

$$v_i^a = 3.6 \frac{l_a}{t_2 - t_1} \quad (2)$$

Where: v_i^a = Speed i in an arc a (km/h); l_a = Longitude of the arc a in metres; t_1 = Passing time in beginning node; t_2 = Passing time in ending node.

Finally, to calculate the average speed within an arc, for a given time period, we used Equation (3). We calculate this speed to establish network impedances, and used it as an input to develop the average time travel prediction model.

$$\bar{v}_a = \frac{\sum_{i=1}^n v_i^a}{n} \quad (3)$$

Where: \bar{v}_a = Average operational speed within arc a ; n = Number of registered speed data points within arc a , during a given time period.

3.4. Calculating Overall Average Accessibility

For this, we base our calculations on the average trip time vector (Tvi), which represents the average travel time from node i to all other nodes in the network. It is widely known that this indicator tends to favour those nodes located towards the centre of the network, since travel times from those nodes to all others are shorter, due precisely to their geographical location. To obtain Tvi , we first calculate the uni-modal distance matrix. Then, after compiling average operational speeds for each arc, we generate a minimum average travel times matrix, in order to minimize average travel times between all nodes in the network. Then, the average trip time vector ($nx1$) is related to the specific geographical coordinates (lat. and long.) for each node. This becomes the ordering matrix ($nx3$), with which we are able to generate isochronous curves for average travel times. We used this approach to analyse four gas station contexts: Context 1, considers all gas stations, without regard for the type of fuel; Context 2, considers only those gas stations distributing ordinary gasoline and Diesel fuel; Context 3, considers only those gas stations distributing premium gasoline; and, Context 4, considers only those gas stations distributing natural gas for vehicular use.

3.5. Calculating the spatial coverage index

The urban area of the city of Manizales comprises 35.1 Km², and its population for 2010, totalled 361.422 inhabitants. The number of housing units accounted for in this area corresponds to 83.868 units, which are distributed throughout 115 neighbourhoods. These data were correlated, via the use of GIS, with the average time travel curves, obtained for the aforementioned contexts. The Spatial Coverage Index – SCI, is defined by Equation (4), and is developed through equations (5) and (6):

$$SCI = \frac{V_x}{V_{x0}} \left[Accessibility \right]_{C_k}^{G_t} \quad (4);$$

Where; C_k = Percentage coverage of K ; $K = 1, 2, \dots, 31$ Gas stations; $G_t = 5, 10, \dots, 50$ isochrones curve; V_x = population, area and housing.

As variables of area, population and number of housing units are accounted for in this index, these will represent a greater impact, as each average time travel curve refers greater coverage. The coverage index varies from 0 to 1; being 1 the greatest spatial coverage. Hence, we were able to estimate the percentages of area, population and number of housing units covered by a particular isochronous curve, which ultimately defines the coverage values for each average time travel curve.



$$C_{k,v} = \left(\%V_x \mid V_x \in C_t \right) \quad (5);$$

Where; $C_{k,v}$ = Percentage of coverage for each Gas Station and for each analysed variable, given an score from zero to one; zero for min. C_v and one for max. C_v

$$SCI = \sum \frac{1}{2^n} * \sum P_v * \frac{C_v - \min(C_v)}{\max(C_v) - \min(C_v)} \quad (6);$$

Where; n = number of isochrones curves; P_v = weight for each analysed variable (population 40%, housing 40% and area 20%).

4. Main results

There are a total of 31 gas stations in the city. The specific results from each of the studied contexts allow us to illustrate the overall relationship between the gas station locations and the operative characteristics of the road network.

4.1. Context 1: Gas Stations without regard for the type of fuel

Initially, we analysed the geospatial location of all gas stations, without focusing on the types of fuel these distribute. The area reporting the greatest accessibility refers an average travel time of 4 minutes (see Figure 1a), thus extending around an ample central sector of the city, and expanding to each side of the main arteries. When analysing the total urban area, we find that in order to reach a gas station it is necessary to invest between 4 and 22 minutes of average travel time, approximately. Figure 1b shows the accumulated percentage of area, population and housing units that is covered by the isochronous curves, where we can perceive similar behaviours from these three key variables. The coverage analyses as referred to the time curves provide us with a better diagnostic on the geospatial location of the gas stations, for the area and housing units variables; the 6 minute curve being the one showcasing a major coverage percentage in this case. For the population variable, however, we find that the 10 minute curve covers the greatest number of people.

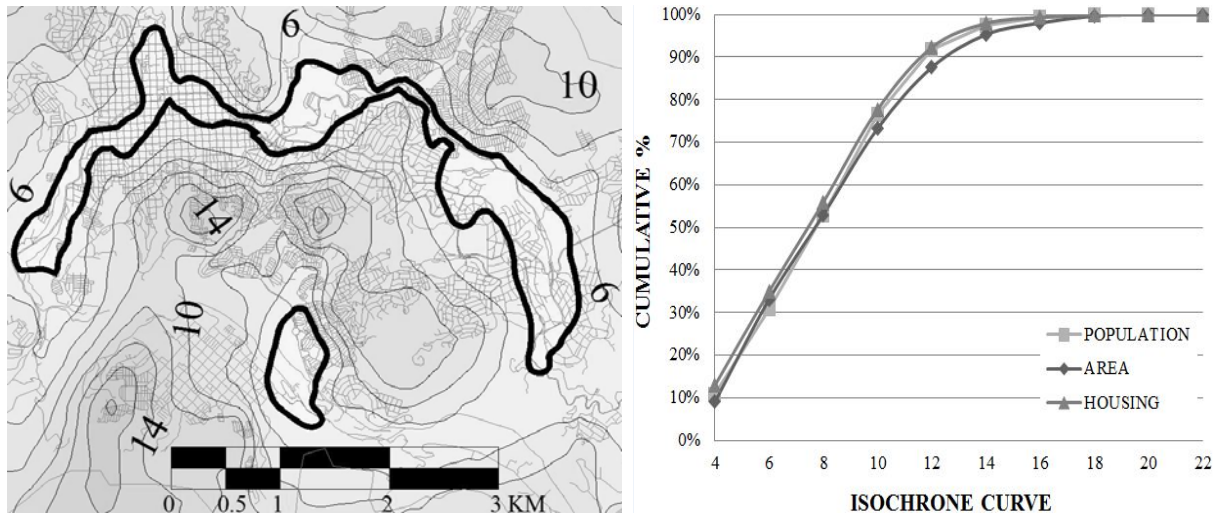


Fig. 1. (a) Isochrone curve; context 1. (b) Cumulative percentage vs. average travel time, isochronous curve; context 1. Source: authors' elaboration.

We can conclude that 50% of the total population can reach a gas station if 7.7 minutes of average travel time are invested; this number decreases to 7.4 minutes when analysing only housing units. We can conclude that 50% of the total population can reach a gas station if 7.7 minutes of average travel time are invested; this number

decreases to 7.4 minutes when focusing only on housing units. The north-west, north-east, and south sectors of the city show the greatest coverage times, which ultimately means these are the areas from which it is hardest to access a gas station.

4.2. Context 2. Gas Stations distributing ordinary fuel and Diesel.

Out of the 31 gas stations, 30 of these distribute ordinary gas and 29 distribute Diesel. Our results do not exhibit major differences from those previously obtained in context 1. However, we can observe that the west and south sectors of the city reveal the most deficient coverage times.

4.3. Context 3 Gas Stations distributing premium fuel.

58% (18) of the gas stations in the city distribute premium fuel. The shortest average travel time that must be invested in order to reach a gas station of this type is 4 minutes (see Figure 2a). Within this context, we find that the city is covered by curves corresponding to average travel times between 4 and 34 minutes (see Figure 2b); the 10 minute curve is the one referring a greater percentage for the three variables (area, population, housing units).

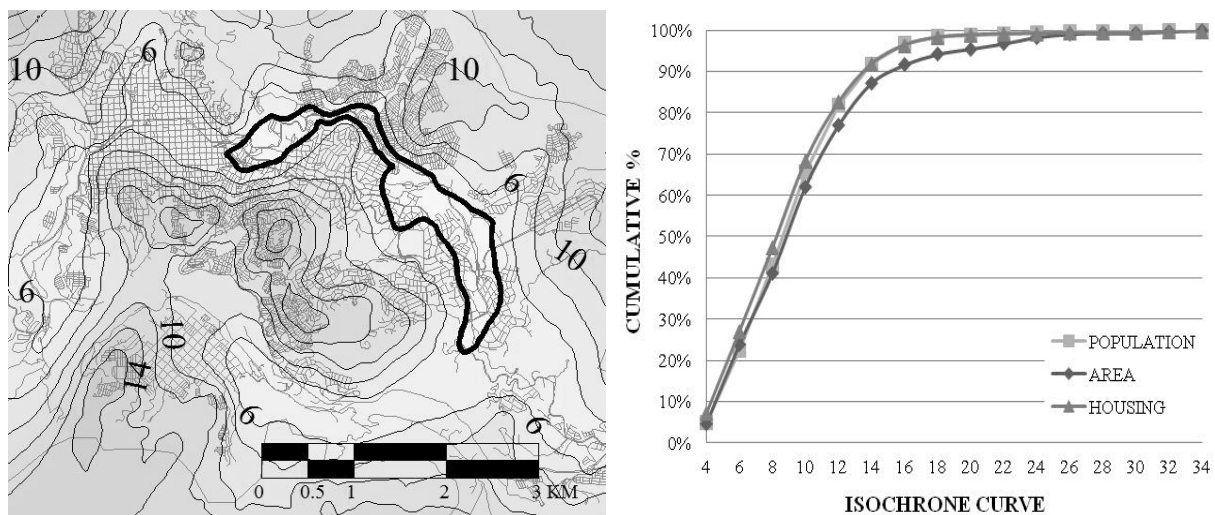


Fig. 2. (a) Isochrone curve; context 3; (b) Cumulative percentage vs. average travel time, isochronous curve; context 3. Source: Authors' elaboration.

When comparing the results from contexts 1 and 3, and focusing on the population variable, we observe that within context 1, 100% of it is covered by an average travel time of 18 minutes, while for context 3, only 98% of the population is covered by the same time curve; thus representing a difference of 7950 inhabitants. Furthermore, for the 4 minute curve, context 3 refers a greater coverage difference, with respect to context 1, this time represented in 23150 inhabitants. We can conclude that 50% of the total population can reach a gas station if 8.6 minutes of average travel time are invested; this number decreases to 8.3 minutes when focusing only on housing units. These findings indicate that it is necessary to make greater time investments to find a gas station that distributes premium fuel, as compared to context 1. The central and western sectors of the city showcase the greater operative limitations to reach a premium fuel gas station, which is not the case for the eastern sectors of the city. It is appropriate to mention here, that it is this eastern sector of the city, which hosts a vast percentage of high socioeconomic strata lands.

4.4. Context 4 Gas Stations distributing Natural Gas for Vehicular Use (CNG).

39% (12) of the gas stations in the city distribute CNG. The shortest average travel time curve corresponds to 4 minutes, extending over the main corridor between the eastern sector of the city and the CBD. In this specific context, the city is covered by average travel time curves between 4 and 40 minutes. Hence, in order to reach a gas station distributing CNG, the maximum travel time corresponds to approximately 40 minutes. The 8 minute curve showcases the greatest coverage percentage for the population and housing units variables. Similarly, we



find that 90% of the population can reach a CNG distributing gas station investing a maximum average travel time of 16 minutes. When comparing the obtained results with the previously analysed contexts, and focusing on the population variable, we observe that while 100% of the population (in contexts 1 and 2) is covered with 18 minutes of average travel time, for context 3, this same time curve only covers 98% of the population. Moreover, for context 4, we find that this number only corresponds to 93%. For this fourth scenario we find that 50% of the population can reach a CNG gas station if 8.9 minutes of average travel time are invested; a number which decreases to 8.6 minutes when focusing only on housing units. This provides clear indication that it is necessary to invest greater travel times to reach a CNG gas station than one distributing ordinary or premium fuel. Likewise, we highlight the fact that most of the CNG gas stations are located along the main east-west corridor (and vice versa), denoting a significant deficit of CNG gas stations along the north-south corridor.

4.5. Spatial Coverage Indices (SCI)

To calculate the spatial coverage indices for each gas station, we took the coverage percentages obtained in Context 1, for the three key variables (area, population, housing units). Applying the previously described methodology, we found a variation for the SCI ranging from 0.06 to 0.85. Figure 3 describes the spatial location of all gas stations analyzed in this research, graphically distinguishing between those obtaining a high SCI ($SCI > 0.75$; rhombi), and those with a low SCI ($SCI < 0.1$; stars).

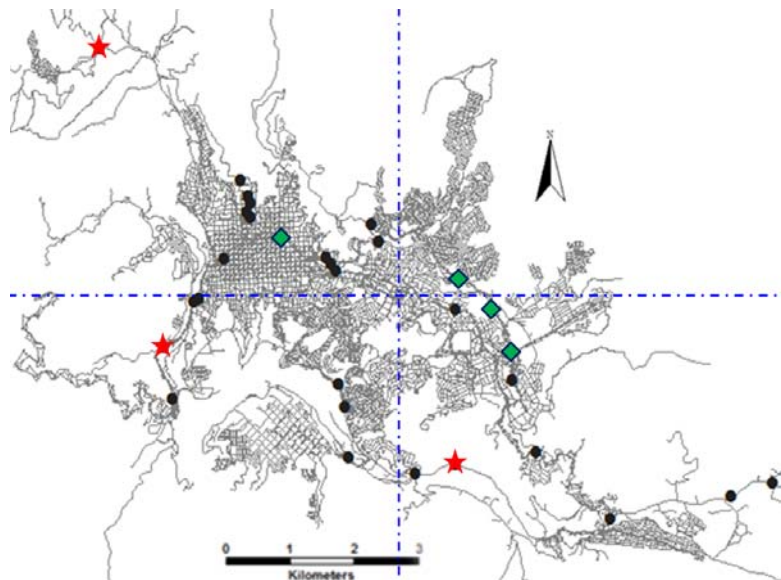


Fig. 3. Spatial location of all gas stations. High SCI (rhombi); low SCI (stars). Source: Authors' elaboration.

Overall, both high SCI and low SCI gas stations are located across the main vehicular corridor of the city. However, we find that four of these showcase a very high SCI, while three of these exhibit a very low SCI. By dividing the city in quadrants, we are able to highlight the following key points:

- The quadrants with the greater number of gas stations correspond to the northwest and south east quadrants, with a total of 13 and 10 gas stations, respectively.
- The northeastern quadrant showcases only one gas stations; nevertheless, this precise one reports a significantly high SCI of 0.76.
- Out of all gas stations, only 35% (11) of these report an SCI higher to 0.5, out of which seven are located within the northwestern quadrant; hence, 54% of the gas stations located within this quadrant have an SCI greater to 0.5.
- Through a cumulative distribution function, we find that 50% of the gas stations in the city, showcase SCI values lower tan 0.35, which is considered to be a low value in this case.
- All gas stations located in the southeastern quadrant report SCI values lower tan 0.29.
- When calculating an average SCI for each quadrant, we obtain the following order: northeast (0.76), northwest (0.48), southeast (0.41) and southwest (0.17). If we ponder these values by the number of gas



stations, the values would otherwise be: northwest (0.2), southeast (0.13), southwest (0.04) and northeast (0.02).

5. Conclusions

It is possible to reach a gas station in the city of Manizales within an average travel time of between 4 and 22 minutes. The worst scenario is found for CNG stations, as reaching one implies an average time investment of between 4 and 40 minutes. The importance of the location patterns of activity nodes has been recognized as one of the crucial factors influencing local and regional economic development. This is applicable both to urban and regional levels.

Through analysing Spatial Coverage Indices, we can conclude that there are two specific sectors of the city where it is feasible to locate a new gas station; namely the southwestern and northeastern sector. We also conclude that those gas stations reporting greater coverage levels, thus implying a better relationship between their geospatial location and the operative characteristics of the city's road network, are located in the central and eastern sectors.

From a social perspective, we know that a greater accessibility in transport contributes to greater social inclusion, as it allows for greater access to the typical activities of society (Farrington and Farrington, 2005). Therefore, activity nodes must be adequately distributed within a territory in order to maximize accessibility. In this respect, we observe that the northwestern sector exhibits sub-sectors with a highly biased vocation towards gas distribution. Although this can be explained due to the specific economic activities performed in this zone, it does not represent a distribution aiming to supply a service provision need.

We further observe that those gas stations reporting a lower SCI are located along heavy traffic corridors, providing an entrance or exit to the city. Hence, it is crucial that future research on this topic considers the inclusion of additional variables such as daily average traffic flows for those roads reaching gas stations, as well as the stock of private cars in the city. Both of these variables, for instance, could provide a greater range to examine the optimal locations for such activity nodes.

We propose that future contributions in this arena consider being complemented with visual tools that clearly represent the effects of accessibility changes. This would allow a better understanding – from the perspective of mobility planning – of the sectors towards which a greater impact in terms of social coverage is expected.

Analyses such as this are useful to complement urban planning activities in general, and permit issuance for urban infrastructure interventions, in particular. Likewise, we propose the construction of an intervention plan or activity node expansion, based on the application of the SCI hereby described. Such an activity (and considering the recent trends in sustainable energy for transport) would probably demonstrate a need for a systematic definition of the best locations, for stations providing vehicular electric charging. In such a case, this research could be replicated and applied. This research was presented to Public Authorities.

Acknowledgements

This research was funded by the “*Semilleros de Investigación*” scheme of the National University of Colombia – Manizales Branch, 2012.

References

- Alonso, W. (1964). *Location and Land Use*. Cambridge, MA: Harvard University Press.
- Arcidiacono, C. (2010). A model to manage crop-shelter spatial development by multi-temporal coverage analysis and spatial indicators. *Biosystems Engineering*. Vol.107, 107-122.
- Batty, M. (2009). Accessibility: in search of a unified theory. *Environment and Planning B: Planning and Design*, Vol. 36, 191-194.
- Biehl, D. (1991). The role of infrastructure in regional development. (Pion, Ed.) *Infrastructure and Regional Development*, 9-35.
- Bocarejo S., J.P. & Oviedo H., D.R., 2012. Transport accessibility and social inequities: a tool for identification of mobility needs and evaluation of transport investments. *Journal of Transport Geography*.



Burns, C.M. and Inglis, A.D. (2007). Measuring food access in Melbourne: Access to healthy and fast foods by car, bus and foot in an urban municipality in Melbourne. *Health & Place* 13, 877-885.

Calcuttawala, Z. (2006). Landscapes of Information and Consumption: A Location Analysis of Public Libraries in Calcutta, in Edward D. Garten, Delmus E. Williams, James M. Nyce (ed.) 24 (Advances in Library Administration and Organization, Volume 24), Emerald Group Publishing Limited. pp.319-388.

Cheng, J., Bertolini, L. & Clercq, F. (2007). Measuring Sustainable Accessibility. *Transportation research Board: Journal of the Transportation Research Board*. Vol. 2017, 16-25.

Escobar, D., García, F. & Cadena, C. (2013). Political determinants and impact analysis of using a cable system as a complement to an urban transport system. *Proceedings of 1st International Conference on Innovation and Sustainability – ICOIS 2013. Redesigning Relationships for Government, Business and Community*. Kuala Lumpur (Malaysia).

Farrington, J. and Farrington, C. (2005). Rural accessibility, social inclusion and social justice: towards conceptualisation. *Journal of Transport Geography*, 13 (1), 1-12.

Fujita, M., Krugman, P., & Venables, A.. (1999). *The Spatial Economy. Cities, Regions and International Trade*. Cambridge, MA: MIT Press.

Gellrich, M. & Zimmermann, N. (2007). Investigating the regional-scale pattern of agricultural land abandonment in the Swiss mountains: A spatial statistical modelling approach. *Landscape and Urban Planning*. Vol.79, 65-76.

Geurs, K., & Ritsema van Eck, J. (2001). *Accessibility Measures: Review and Applications. Evaluation of Accessibility Impacts of Land-use Transport Scenarios, and Related Social and Economic Impacts*. Recuperado el 04 de 08 de 2011, de National Institute of Public Health and the Environment.: <http://www.rivm.nl/bibliotheek/rapporten/408505006.pdf>

Geurs, K., & Van Wee, B. (2004). Accessibility evaluation of land-use and transport strategies: review and research directions. *Journal of Transport Geography*. Vol.12 (2), 127-140.

Gutierrez, J., Condeco-Melhorado, A. & Martín, J. (2010). Using Accessibility indicators and GIS to assess spatial spillovers of transport infrastructure investment. *Journal of Transport Geography*. Vol.18, pp. 141-152.

Halden, D. (2011). The use and abuse of accessibility measures in UK passenger transport planning. *Transportation Business & Management*. Vol.2, 12-19.

Hansen, W. (1959). How accessibility shapes land use. *Journal of the American Institute of Planners*. Vol. 25 (2), 73-76.

Hernandez, J., Rodriguez, M., Rodriguez, N., Santos, R., Morales, E., Cruz, C., y otros. Cobertura geográfica del sistema mexicano de salud y análisis espacial de la utilización de hospitales generales de la Secretaria de salud en 1998. *Salud pública de México*. Vol.44 (6), 519-532.

Higgs, G., Langford, M. & Fry, R. (2012). Investigating variations in the provision of digital services in public libraries using network-based GIS models. *Library & Information Science Research*. Available online 13 November 2012.

Holl, A. (2007). Twenty years of accessibility improvements. The case of the Spanish motorway building programme. *Journal of Transport Geography*. Vol.15 (4), 286-297.

Huiping, L. & Qiming, Z. (2010). Developing urban growth predictions from spatial indicators based on multi-temporal images. *Computers, Environment and Urban Systems*. Vol. 29, 580-594.

Jones, P. (2011). Developing and applying interactive visual tools to enhance stakeholder engagement in accessibility planning for mobility disadvantaged groups. *Transportation Business & Management*. Vol.2, 29-41.



Jones, S. (1981). *Accessability measures: a literature review*. TRRL Report 967, Transport and Road Research Laboratory, Crowthorne, Berkshire.

Kastenholz, E., Eusébio, C., Figueiredo, E. & Lima, J. (2012). Accessibility as Competitive Advantage of a Tourism Destination: The Case of Lousã, in *Field Guide to Case Study Research in Tourism, Hospitality and Leisure* (Advances in Culture, Tourism and Hospitality Research, Volume 6, K.F. Hyde, C. Ryan and A.G. Woodside (ed.)), Emerald Group Publishing Limited. pp.369-385.

Kotavaara, O., Antikainen, H., & Rusanen, J. (2011). Population change and accessibility by road and rail networks: GIS and statistical approach to Finland 1970–2007. *Journal of Transport Geography*, Vol. 19(4), 926–935.

Krugman, P. (1991). Increasing returns and economic geography. *Journal of Political Economy*, Vol.99(3), 483–499.

Li, Q., Zhang, T., Wang, H. & Zeng, Z. (2011). Dynamic accessibility mapping using floating car data: a network-constrained density estimation approach. *Journal of Transport Geography* 19, 379-393.

López, E., Gutierrez, J. & Gómez, G. (2008). Measuring regional cohesion effects of large-scale transport infrastructure investment: an accessibility approach. *European Planning Studies*. Vol.16(2), pp. 277–301.

MacKinnon, D., Pirie, G., & Gather, M. (2008). Transport and economic development. En R. Knowles, J. Shaw, & I. Docherty (Edits.), *Transport Geographies: Mobilities, Flows and Spaces* (págs. 10-28). Oxford: Blackwell Publishing.

Martellano, D., Nijkamp, P. & Reggiani, A. (1995). *Measurement and Measures of Network Accessibility*. TI 5-95-207, Tinbergen Institute, Amsterdam.

Morris, J., Dumble, P. & Wigan, M. (1978). Accessibility indicators in transport planning. *Transportation Research, A*. Vol. 13, 91-109.

Park, S. (2012). Measuring public library accessibility: a case study using GIS. *Library & Information Science Research*. Vol.34 (1), pp. 13-21.

Petrus, J. & Segui, J. (1991). *Geografía de Redes y Sistemas de Transporte*. Madrid. España.: Síntesis.

Pirie, G. (1979). Measuring accesibility: a review and proposal. *Environment and Planning A*. Vol. 11, 299-312.

Rietveld P. & Nijkamp P. (1993). Transport and regional development. In: J. Polak and A. Heertje, Editors, *European Transport Economics*, European Conference of Ministers of Transport (ECMT), Blackwell Publishers, Oxford.

Sailer, K., Marmot A. & Penn, A. (2012). Spatial Configuration, Organisational Change and Academic Networks. ASNA 2012 – Conference for ‘Applied Social Network Analysis’, Zürich, Switzerland, 4-7.

Schürman, C., Spiekermann, K. & Wegener, M. (1999). *Accessibility indicators*. Berichte aus dem Institut für Raumplanung, 39, IRPUD, Dortmund.

Straatemeier, T. (2008). How to plan for regional accessibility?. *Transport Policy*. 127-137.

Tassinari, P., Carfagna, E., Benni, S. & Torreggiani, D. (2008). Wide-area spatial analysis: A firsts methodological contribution for the study of changes in the rural built environment. *Biosystems Engineering*. Vol. 100, 435-447. (2008).

Vega, A. (2011). A multi-modal approach to sustainable accessibility in Galway. *Regional Insights*. Vol.2(2), 15-17.



Vickerman, R., Spiekermann, K. & Wegener, M. (1999). Accessibility and economic development in Europe. *Regional Studies*, Vol. 33, 1-15.

Zhu, X. & Liu, S. Analysis of the impact of the MRT system on accessibility in Singapore using an integrated GIS tool. *Journal of Transport Geography*. Vol. 4(12), 89-101, (2004).

The UNU-MERIT WORKING Paper Series

- 2014-01 *The medium-term effect of R&D on firm growth* by Marco Capasso, Tania Treibich and Bart Verspagen
- 2014-02 *Diverse and uneven pathways towards transition to low carbon development: The case of diffusion of solar PV technology in China* Michiko Iizuka
- 2014-03 *User innovators and their influence on innovation activities of firms in Finland* by Jari Kuusisto, Mervi Niemi and Fred Gault
- 2014-04 *Migration, remittances and household welfare in Ethiopia* by Lisa Andersson
- 2014-05 *Path-breaking directions of nanotechnology-based chemotherapy and molecular cancer therapy* by Mario Coccia and Lili Wang
- 2014-06 *Poor trends - The pace of poverty reduction after the Millennium Development Agenda* Richard Bluhm, Denis de Crombrughe, Adam Szirmai
- 2014-07 *Firms' adoption of international standards: Evidence from the Ethiopian floriculture sector* by Mulu Gebreeyesu
- 2014-08 *School choice, segregation, and forced school closure* by Cheng Boon Ong and Kristof De Witte
- 2014-09 *Gender difference in support for democracy in Sub-Saharan Africa: Do social institutions matter?* by Maty Konte
- 2014-10 *Why are women less democratic than men? Evidence from Sub-Saharan African countries* by Cecilia García-Peñalosa and Maty Konte
- 2014-11 *Tipping points? Ethnic composition change in Dutch big city neighbourhoods* by Cheng Boon Ong
- 2014-12 *Technology life cycle and specialization patterns of latecomer countries. The case of the semiconductor industry* by Giorgio Triulzi
- 2014-13 *Patents as quality signals? The implications for financing constraints on R&D* by Dirk Czarnitzki, Bronwyn H. Hall and Hanna Hottenrott
- 2014-14 *Assessment of effectiveness of Chinese aid in competence building and financing development in Sudan* by Samia Satti Osman Mohamed Nour
- 2014-15 *Education, training and skill development policies in Arab Gulf countries: Macro-micro overview* by Samia Satti Osman Mohamed Nour
- 2014-16 *Structure of labour market and unemployment in Sudan* by Samia Satti Osman Mohamed Nour
- 2014-17 *Overview of knowledge transfer in MENA countries - The case of Egypt* by Samia Satti Osman Mohamed Nour
- 2014-18 *The impact of ICT in public and private universities in Sudan* by Samia Satti Osman Mohamed Nour
- 2014-19 *End-user collaboration for process innovation in services: The role of internal resources* by Mona Ashok, Rajneesh Narula and Andrea Martinez-Noya
- 2014-20 *Public investment and regional politics: The case of Turkey* by Mehmet Guney Celbis, Denis de Crombrughe and Joan Muysken
- 2014-21 *Infrastructure and the international export performance of Turkish regions* by Mehmet Guney Celbis, Peter Nijkamp and Jacques Poot
- 2014-22 *Discovering and explaining work-family strategies of parents in Luxembourg* by Nevena Zhelyazkova
- 2014-23 *Parental leave take up and return to work of mothers in Luxembourg: An application of the model of nested dichotomies* by Nevena Zhelyazkova

- 2014-24 *Millennium Development Goals: Tool or token of global social governance?* by Mueid Al Raee, Elvis Amoateng, Elvis Korku Avenyo, Youssef Beshay, Mira Bierbaum, Charlotte Keijser and Rashmi Sinha
- 2014-25 *One Europe or several? Causes and consequences of the European stagnation* by Jan Fagerberg and Bart Verspagen
- 2014-26 *The harmony of programs package: Quasi-experimental evidence on deworming and canteen interventions in rural Senegal* by Théophile Azomahou, Fatoumata Diallo and Wladimir Raymond
- 2014-27 *Country Terms of Trade 1960-2012: Trends, unit roots, over-differencing, endogeneity, time dummies, and heterogeneity* by Thomas Ziesemer
- 2014-28 *The structure and comparative advantages of China's scientific research - Quantitative and qualitative perspectives* by Lili Wang
- 2014-29 *Transition to knowledge-based economy in Saudi Arabia* by Samia Satti Osman Mohamed Nour
- 2014-30 *Challenges and opportunities for transition to knowledge-based economy in Arab Gulf countries* by Samia Satti Osman Mohamed Nour
- 2014-31 *Migration of international students and mobilizing skills in the MENA Region* by Samia Satti Osman Mohamed Nour
- 2014-32 *Beyond product innovation; improving innovation policy support for SMEs in traditional industries* by René Wintjes, David Douglas, Jon Fairburn, Hugo Hollanders and Geoffrey Pugh
- 2014-33 *The impact of innovation support programmes on SME innovation in traditional manufacturing industries: an evaluation for seven EU regions* by Dragana Radicic, Geoffrey Pugh, Hugo Hollanders and René Wintjes
- 2014-34 *Beliefs dynamics in communication networks* by Théophile T. Azomahou and Daniel C. Opolot
- 2014-35 *Stability and strategic diffusion in networks* by Théophile T. Azomahou and Daniel C. Opolot
- 2014-36 *Epsilon-stability and the speed of learning in network games* by Théophile T. Azomahou and Daniel C. Opolot
- 2014-37 *Afghan unaccompanied minors in the Netherlands: Far away from home and protected?* by Carla Buil and Melissa Siegel
- 2014-38 *Multinational production and trade in an endogenous growth model with heterogeneous firms* by Hibret B. Maemir and Thomas Ziesemer
- 2014-39 *The political economy of research and innovation in organic photovoltaics (OPV) in different world regions* by Serdar Türkeli and René Kemp
- 2014-40 *Towards the societal system of innovation: The case of metropolitan areas in Europe* by Serdar Türkeli and René Wintjes
- 2014-41 *To return permanently or to return temporarily? Explaining migrants' intentions* by Özge Bilgili and Melissa Siegel
- 2014-42 *Catching up and lagging behind in a balance-of-payments-constrained dual economy* by Alejandro Lavopa
- 2014-43 *An introduction to the economics of rare earths* by Eva Bartekova
- 2014-44 *The unequal effect of India's industrial liberalization on firms' decision to innovate: Do business conditions matter?* By Maria Bas and Caroline Paunov
- 2014-45 *Insurgents in motion: Counterinsurgency and insurgency relocation in Iraq* by Pui-hang Wong

- 2014-46 *Successive leadership changes in the regional jet industry* by Daniel Vertesy
- 2014-47 *Demand, credit and macroeconomic dynamics: A microsimulation model* by Huub Meijers, Önder Nomaler and Bart Verspagen
- 2014-48 *Accessibility analysis as an urban planning tool: Gas station location* by D.A. Escobar , C. Cadena-Gaitán, F.J. Garcia